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A Photographic Key for the Identification of Mammalian Hairs of Prey Species in Snow Leopard (*Panthera uncia*) Habitats of Gilgit-Baltistan Province of Pakistan

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Abstract.-The study of mammalian hair is important in cross-species comparisons in zoological disciplines. Obvious differences have been found in the widths of cortex and medulla at the mid shaft region of the guard hairs. Other important difference includes the hair scale patterns. In this study seven hair characteristics viz., i) average number of scales across mid-shaft region, ii) average scale diameter (µ), iii) diameter of hair at mid-shaft region (µ), iv) medulla diameter (µ), v) cuticular patterns, vi) medulla patterns and vii) pigmentation were used for the development of reference key. The key is based on the guard hair samples collected from the abdominal region of the five domestic mammals *viz.* cattle, yak, domestic sheep, goat, and zo/zomo (yak and cattle hybrid), and five wild mammals viz., ibex, markhor, musk deer, marmot and pika. This key may be used for the identification of hairs found in the scats of carnivorous species present in snow leopard habitat in Gilgit Baltistan province of Pakistan.

Keywords: Scales, medulla, diameter, ungulates, scats, mammals, carnivores, guard hair

INTRODUCTION

The morphological characters of mammalian hairs have the main interest to the researchers for species identification. Hairs contain biologically important intraspecific features which is a useful tool for wildlife zoologists (Davis, 2010). Microscopic examinations of hair width, length, and other variables on hair samples often help to find out what species the hair belongs to, especially if multiple features are considered (Sahajpal *et al.*, 2008). Hair scale patterns formed by the cuticle and hair cross-sectional patterns formed by the cortex and medulla are the two main characteristics used in species recognition (Moyo, 2005).

Wild and domestic ungulates are the main staples of predators' diet according to local abundance. Carnivore predation on livestock is the major socio-economic factor enhancing the persecution of predators. Knowledge of predators' diet is significant for conservation point of view. The study of carnivore food habits from the examination of prey hairs present in scats has been widely accepted and used for describing the diet of mammalian predators, because of non-destructiveness of hairs and easily available scats at all times (De-Marinis and Asprea, 2006).

The only identifiable structure which retains its characteristics during the digestion process is hair (Oli, 1993). Although many variations exist between hair structures of different groups of animal species but the hair structures of many related and unrelated species may be similar. The use of hair reference key could be helpful in this regard. An identification key to the hairs of wild and domestic ungulates can be a valid practical application in studies on feeding habits of wolf (*Canis lupus*), fox (*Vulpes* spp.) and snow leopard (*Panthera uncia*), the carnivores occurring in the snow leopard habitat.

In the past, attempts were made to develop descriptive keys of mammalian hairs (Mathaik, 1938; Mayer, 1952; Stains, 1958). Methods of direct comparison by microscopy have also been used but they are all time consuming (Oli, 1993). Photographic reference key has been proved the best and easy method for the comparison of characteristics of hairs recovered from the scats of carnivores (Oli, 1993). Oli (1993) studied the prey remains in scats, particularly hairs, which are widely used to study diet of mammalian predators; the identification of hairs however is often difficult

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because hair structures vary considerably within different species. Use of photographic reference of diagnostically important hair structures from mammals occurring in a predator's habitat has been found convenient for routine identification.

In this study, a photographic hair reference key of wild and domestic ungulates and small mammals of snow leopard habitat in the Himalayas and Karakoram areas of Gilgit Baltistan Pakistan was developed. The reference cuticular scale patterns, medullary characteristics and measurements were used for identification of the mammalian prey in snow leopard scats in surveyed areas comprising central Karakoram and the western Himalayan mountain ranges of the Gilgi-Baltistan province of Pakistan.

MATERIALS AND METHODS

The study areas comprise central Karakoram and the western Himalayan mountain ranges of the Gilgit Baltistan province of Pakistan. The study sites included Beisil, Seisko, and Zill Villages located in Basha Valley (75°26'E, 35°59'N), Hushey Valley (76°20'E, 35°27'N), Basho valley (75°15'E, 35°25'N), Krabathang Valley (75°19'E, 35°33'N), and Sadpara Lake Valley (75°38'E, 35° 13'N).

Oli (1993) and Jackson (1996) used a combination of hair characteristics such as medullary pattern, hair width and medulla width (measured as a percentage of hair width) as criteria for identifying Himalayan mammal prey species of the snow leopard rather than only the cuticular characteristics of the hairs. For the identification of prey species, the present study depended on the medullary pattern of hair, the widths of medulla and hair at the thickest portion and on the cuticular scale patterns as described by Moore *et al.* (1974).

The clean and dry hair were examined visually or studied under a binocular microscope. Different types of hair present in each scat sample were separated; it is often possible to differentiate the major prey groups, such as small and large mammals, only on the basis of the texture and color of hair after examining them visually or under a binocular microscope. Cross-sections, whole mounts, and scale casts of each hair present in the scats of the snow leopard were prepared. The hairs were then grouped and sub-grouped on the basis of cross-sectional appearance and arrangement of medulla, which made further comparisons easier. Hair reference collection of all the potential prey species of snow leopard indicated by Jackson (1996) and Roberts (1997) was based on representative hairs collected from museum specimens, carcass remains found in the field, and skins owned by villagers. The hairs of small mammals were obtained from the field caught specimens. Prey species were ascertained after making a detailed comparison of all hair characteristics with a photographic key of five domestic mammals viz., sheep (*Ovis aries*), goat (*Capra hircus domesticus*), yak (*Bos grunniens*), cow (*Bos taurus)* and *zo/zomo* (the cross between cattle and yak), and as many free living wild mammals viz., Himalayan ibex (*Capra ibex sibirica*), Astore markhor (*Capra falconeri falconeri*), musk deer (*Moschus chrysogaster*), marmot (*Marmota caudata*) and pika (*Ochotona roylei*). Adopting the procedure of Oli (1993), slides of whole mount, cross section and scale replica were prepared. Microphotographs of the representative cross-sections, medulla and scale patterns along the length of the hairs of each species were taken at different magnifications by using a digital camera for microscope DCM35 (350k pixels, USB 1.0). Both scale patterns and medullary arrangements along the length of an individual hair varied considerably; hence many photographs of each of these structures were taken for each species. However in the key, only photographs of representative and predominant patterns were included to avoid confusion. The key has been used for the identification of hairs in scat samples and determination of prey consumed by the snow leopard (Anwar *et al.*, 2011) and other carnivores in the Baltistan area.

RESULTS

Prey items in the study area were identified by developing a reference photographic key (Figs. 1-10). All potential mammalian prey species inhabiting the Baltistan area were included in the reference key. This photographic key contains 10 species; five species from the wild and five of the

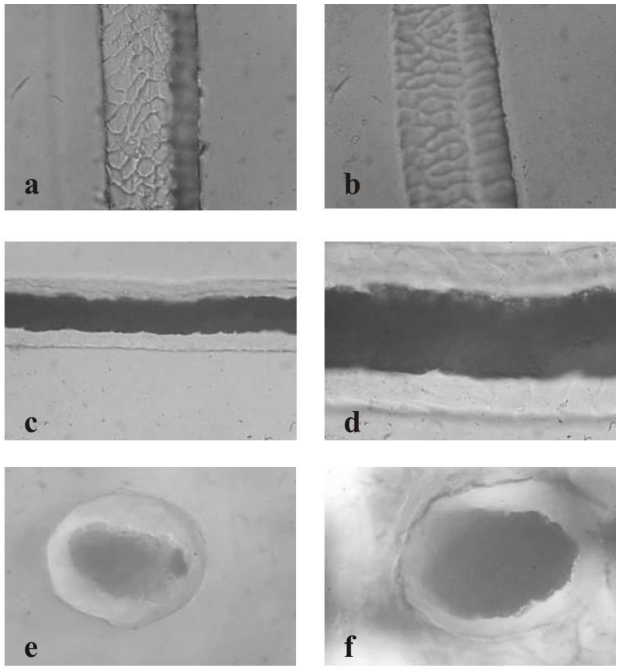

Fig. 1. Microphotographs showing various structures of the guard hair of domestic sheep (*Ovis aries*). a, Scale replication: negative impression at mid-shaft region (40X); b, Scale replication: negative impression near tip region (40X); c, Whole mount at mid-shaft region (40X); d, Whole mount at mid-shaft region (100X); e, Cross section at mid-shaft region (40X); f, Cross section at mid-shaft region (100X).

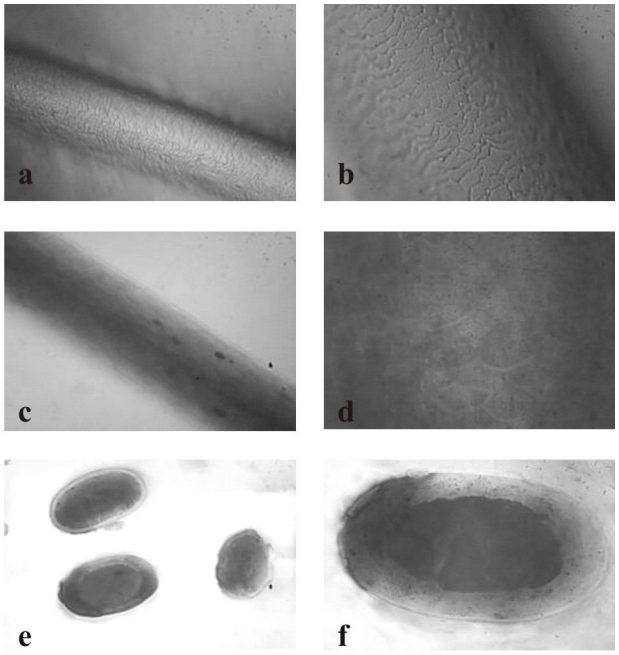

Fig. 2. Microphotographs showing various structures of the guard hair of domestic goat (*Capra hircus domesticus*). a, Scale replication: positive impression near tip region (40X); b, Scale replication: positive impression at mid-shaft region (100X); c, Whole mount at mid-shaft region (40X); d, Whole mount near tip region (100X); e, Cross section of various hairs (40X); f, Cross section at mid-shaft region (100X).

domestic mammals (Table I). The photographic reference key developed in this study was successfully used for the identification of prey species in the scats of snow leopard (Anwar *et al*., 2011). The identification key was improved by using the cross section details, pigmentation in cortex and medulla patterns in addition to scale patterns. Average number of scales across mid-shaft region, average diameter of primary guard hair at mid-shaft region, average scale diameter, average medulla diameter along with cuticular and medulla patterns were used as a diagnostic tool in this study (Table II).

The detailed measurements of hair characteristics of prey species have been given in Table II.

Table I.- The potential mammalian prey species of the snow leopard whose hair photographs were used for identification of unknown hair samples from scats.

Common name	Scientific name	Figures
Domestic mammals		
Domestic Sheep[+]	*Ovis aries*	1
Domestic Goat[+]	*Capra hircus domesticus*	2
Cattle*	*Bos taurus*	3
Zo/Zomo (Cattle and yak hybrid)[++]	*B. taurus* × *B. grunniens*	4
Yak[+]	*Bos grunniens*	5
Wild mammals		
Himalayan Ibex	*Capra ibex sibirica*	8
Markhor	*Capra falconeri falconeri*	9
Musk Deer[+++]	*Moschus chrysogaster*	10
Marmot	*Marmota caudata*	6
Pika	*Ochotona roylei*	7

[+] Pure, native breeds from Basha valley Shigar, Pakistan
[++] F_1 hybrid from Basha valley Shigar, Pakistan
[+++] Kashmir region, Pakistan

Table II.- Diagnostic characteristics of the guard hair of mammalian prey species of the snow leopard.

Species	Average number of scales across mid-shaft region	Diameter of hair at mid-shaft region (µ)	Average scale diameter (µ)	Medulla diameter (µ)	Scales cuticular pattern[+]	Medulla pattern[++]	Pigmentation in cortex
Domestic mammals							
Domestic Sheep	7 (range 3-8)	08	2.5 (range 2-4)	06	Flattened	Intermediate	Transparent
Domestic Goat	5 (range 2-6)	12	2.0 (range 2-6)	08	Crenate	Continuous	Pigmented
Cattle	3 (range 2-4)	11	2.0 (range 2-4)	06	Crenate	Continuous	Heavily pigmented
Zo/Zomo (Cattle and yak hybrid)	4 (range 2-4)	13	1.5 (range 2-4)	08	Crenate	Fragmented	Heavily pigmented
Yak	2 (range 4-6)	09	2.0 (range 2-6)	04	Crenate	Continuous	Heavily pigmented
Wild mammals							
Ibex	5 (range 5-7)	14	2.5 (range 2-5)	11	Crenate	Continuous	Pigmented
Markhor	6 (range 5-8)	17	3.0 (range 2-8)	13	Crenate	Latticed	Pigmented
Musk Deer	14 (range 13-16)	50	3.5 (range 3-5)	28	Flattened	Latticed	Transparent
Marmot	3 (range 3-5)	11	3.0 (range 2-6)	06	Crenate	Latticed	Pigmented
Pika	3 (range 4-5)	08	1.5 (range 1-2)	05	Elongate	Discontinuous	Pigmented

[+]Scales
Flattened, Overlapping scales having flat and untoothed margins; Crenate, Overlapping scales having rounded apex and toothed margins; Elongate, Overlapping scales with tapering point.
[++]Medulla
Intermediate, Irregular shaped medulla; Continuous, Unbroken and uniform medulla; Latticed, Continuous and cellular medulla; Discontinuous, Medulla divided into Disk like segments; Fragmented, Medulla divided into elongated segments.

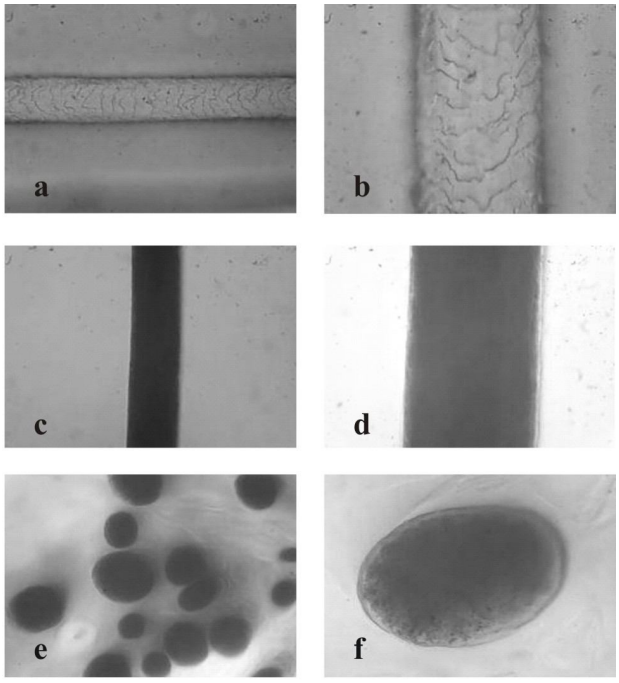

Fig. 3. Microphotographs showing various structures of the guard hair of the ox/ cow (*Bos taurus*). a, Scale replication: negative impression at mid-shaft region (40X); b, Scale replication: negative impression at mid-shaft region (100X); c, Whole mount at mid-shaft region (40X); d, Whole mount at mid-shaft region (100X); e, Cross section of various hairs (40X); f, Cross section at mid-shaft region (100X)

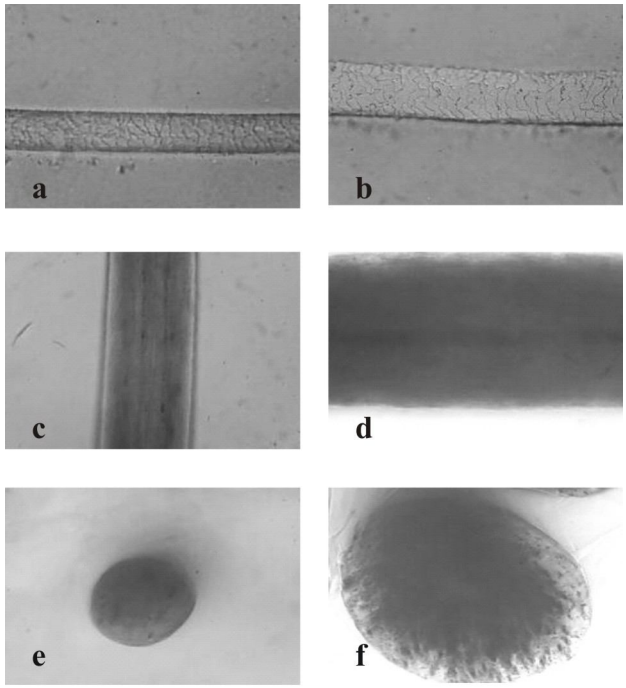

Fig. 4. Microphotographs showing various structures of the guard hair of *zo* / *zomo* (*Yak and Cow F_1 crossbreed*). a, Scale replication: negative impression at mid shaft region (40X); b, Scale replication: negative impression at mid shaft region (100X); c, Whole mount at mid shaft region (40X); d, Whole mount at mid shaft region (100X); e, Cross section at tip region (40X); f, Cross section at mid shaft region (100X).

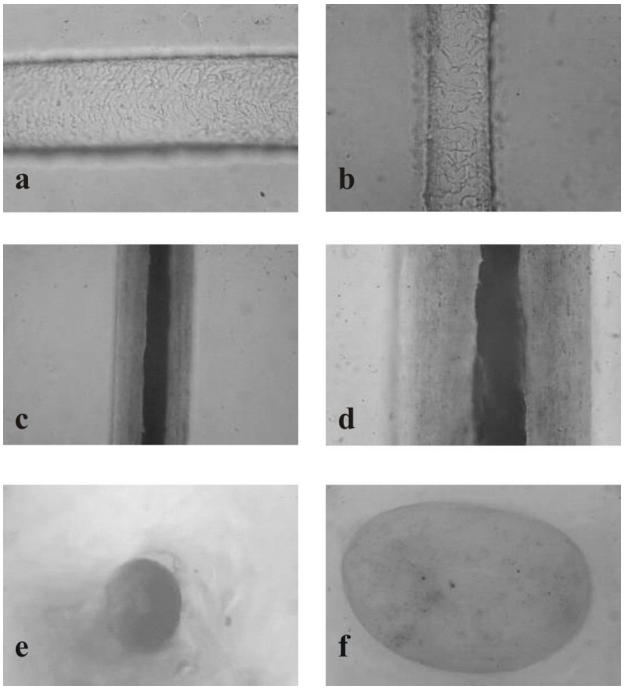

Fig. 5. Microphotographs showing various structures of the guard hair of yak (*Bos grunniens*). a, Scale replication: negative impression at mid-shaft region (40X); b, Scale replication: negative impression at tip region (40X); c, Whole mount at mid-shaft region (40X); d, Whole mount at mid-shaft region (100X); e, Cross section near tip region (40X); f, Cross section at mid-shaft region (100X)

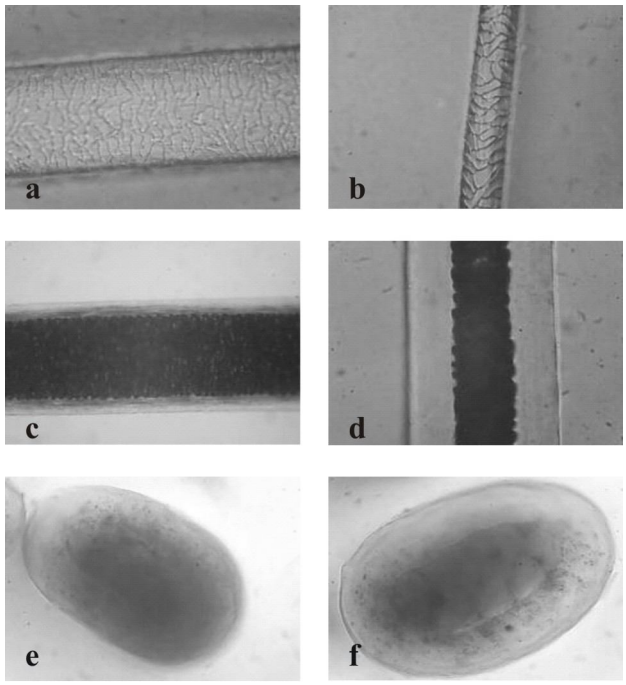

Fig. 6. Microphotographs showing various structures of the guard hair of marmot (*Marmota caudata*). a, Scale replication: negative impression at mid-shaft region (40X); b, Scale replication: negative impression near tip region (40X); c, Whole mount at mid-shaft region (40X); d, Whole mount near tip region (100X); e, Cross section near tip region (100X); f, Cross section at mid-shaft region (100X)

DISCUSSION

The main purpose of this key is to identify the mammalian hairs found in snow leopard scats; the key can also be used for the food study of other mammalian predators found in the central Karakoram and the western Himalayan mountain ranges of the Gilgit-Baltistan province of Pakistan.

Hairs present in fecal matter of carnivore predators are useful investigating tools to know about the mammalian preys that figure in their diets. There are number of problems linked with this method (Brunner and Coman, 1974). These include variation in hair types on the same individual, different scale patterns along the length of an individual hair, and some hair characteristics overlapping between species and cross breeds. The hair characteristics of the yak, cow and their cross breed tend to overlap between them. The hair identification reference key in this study is based on the characteristics of the guard hairs at mid-shaft region of ten mammal prey species. Musk deer was also included in hair reference key though it was not present in the study area. According to the locals musk deer was once present in the area, but it has been eliminated from the area due to intensive hunting.

In Pakistan, the musk deer is associated with the sub alpine scrub zone of the North West Himalayas where it favours steep slopes and narrow gullies near mountain crests. As such it frequents almost the same habitat as does the snow leopard (Roberts, 1997). Although the possibility of finding the deer's hair in the snow leopard faeces was very remote, yet we included the characteristics of the

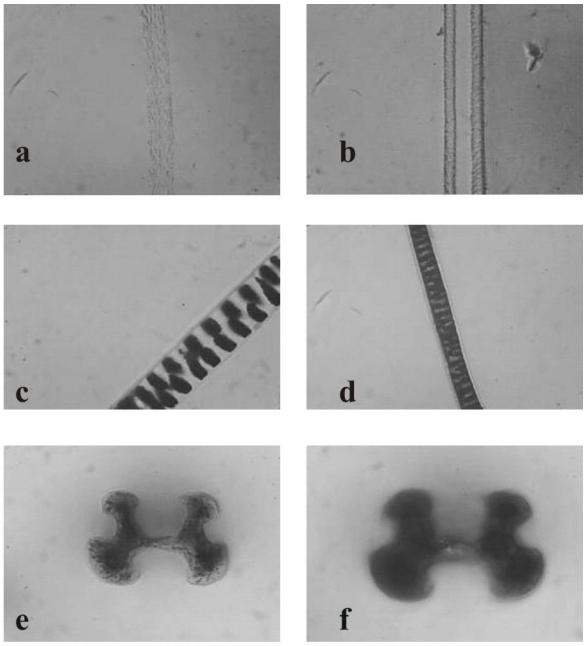

Fig. 7. Microphotographs showing various structures of the guard hair of pika (*Ochotona roylei*). a, Scale replication: negative impression at tip region (40X); b, Scale replication: negative impression at mid-shaft region (40X); c, Whole mount at mid-shaft region (100X); d, Whole mount at mid-shaft region (40X); e, Cross section near tip region (100X); f, Cross section at mid-shaft region (100X)

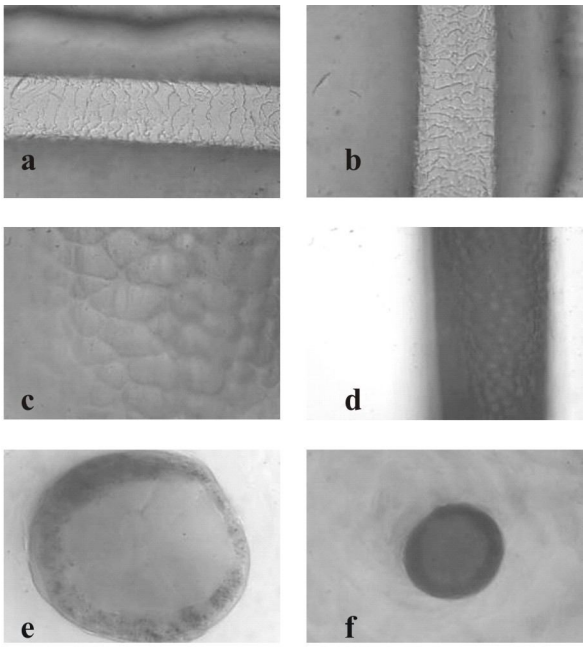

Fig. 8. Microphotographs showing various structures of the guard hair of Himalayan ibex (*Capra ibex sibirica*). a, Scale replication: negative impression near tip region (40X); b, Scale replication: negative impression at mid-shaft region (40X); c, Whole mount at mid-shaft region (100X); d, Whole mount at mid-shaft region (40X); e, Cross section at mid-shaft region (100X); f, Cross section at mid-shaft region (40X)

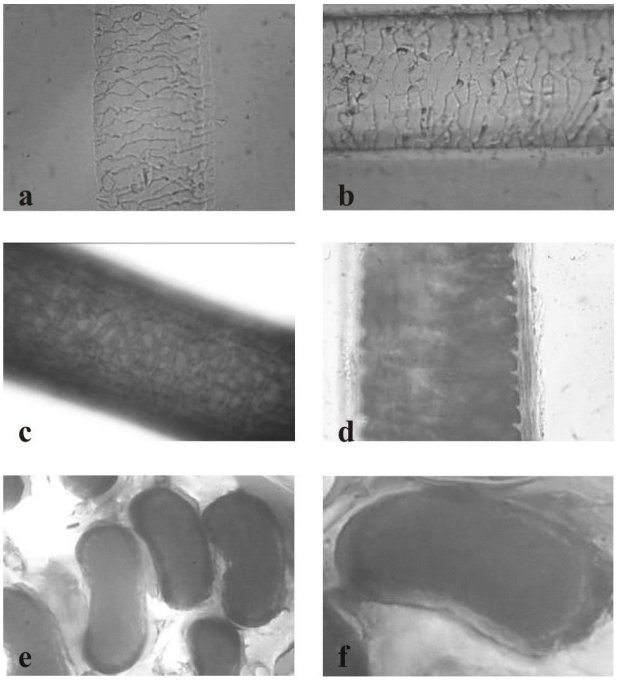

Fig. 9. Microphotographs showing various structures of the guard hair of Astore markhor (*Capra falconeri falconeri*). a, Scale replication: negative impression near tip region (40X); b, Scale replication: negative impression at mid-shaft region (40X); c, Whole mount at mid-shaft region (100X); d, Whole mount at near tip region (100X); e, Cross section at mid-shaft region (40X); f, Cross section at mid-shaft region (100X)

musk deer's guard hairs in our key which could be used in future studies.

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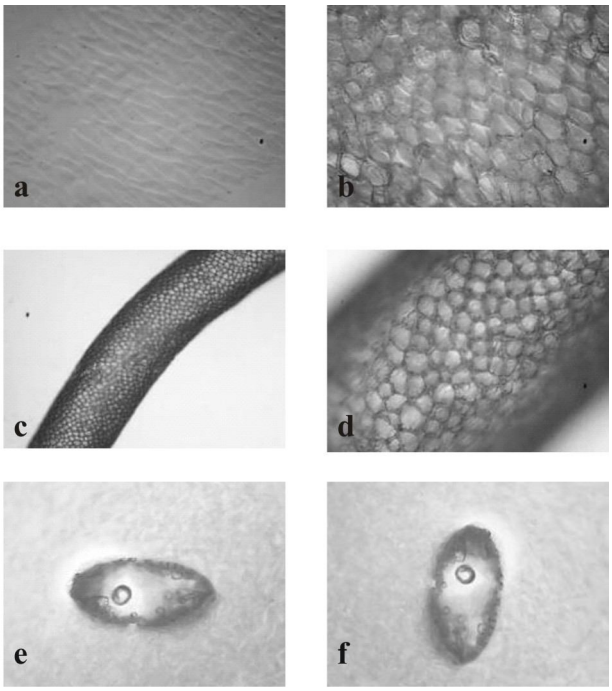

Fig. 10. Microphotographs showing various structures of the guard hair of musk deer (*Moschus chrysogaster*). a, Scale replication: negative impression at mid-shaft region (100X); b, Whole mount at base region (100X); c, Whole mount at mid-shaft region (40X); d, Whole mount at mid-shaft region (100X); e, Cross section at mid-shaft region (100X); f, Cross section at mid-shaft region (100X)

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